

CLAIMS

1. A chemical-mechanical polishing composition comprising:
 - (a) silica particles,
 - (b) about 5×10^{-3} to about 10 mmoles/kg of at least one alkaline earth metal selected from the group consisting of calcium, strontium, barium, and mixtures thereof, based on the total weight of the polishing composition,
 - (c) about 0.1 to about 15 wt.% of an oxidizing agent, and
 - (d) a liquid carrier comprising water,wherein the polishing composition has a pH of about 7 to about 13.
2. The polishing composition of claim 1, wherein the polishing composition has a pH of about 8 to about 11.
3. The polishing composition of claim 2, wherein the silica particles are present in the polishing composition in an amount of about 1 to about 10 wt.% based on the total weight of the polishing composition.
4. The polishing composition of claim 3, wherein the oxidizing agent is an inorganic or organic per-compound.
5. The polishing composition of claim 4, wherein the oxidizing agent is present in the polishing composition in an amount of about 0.5 to about 8 wt.% based on the total weight of the polishing composition.
6. The polishing composition of claim 5, wherein the oxidizing agent is present in the polishing composition in an amount of about 1 to about 5 wt.% based on the total weight of the polishing composition.
7. The polishing composition of claim 4, wherein the polishing composition further comprises an inorganic acid selected from the group consisting of nitric acid, phosphoric acid, sulfuric acid, salts thereof, and combinations thereof.
8. The polishing composition of claim 4, wherein the polishing composition further comprises an organic acid selected from the group consisting of oxalic acid, malic acid, malonic acid, tartaric acid, acetic acid, lactic acid, propionic acid, phthalic acid, benzoic acid, citric acid, succinic acid, salts thereof, and combinations thereof.

9. The polishing composition of claim 8, wherein the polishing composition further comprises a corrosion inhibitor selected from the group consisting of 1,2,3-triazole, 1,2,4-triazole, benzotriazole, benzimidazole, benzothiazole, and mixtures thereof.
10. The polishing composition of claim 9, wherein the polishing composition further comprises a complexing or chelating agent.
11. The polishing composition of claim 1, wherein the alkaline earth metal is present in the polishing composition in a concentration of about 5×10^{-3} to about 7.5 mmoles/kg.
12. The polishing composition of claim 11, wherein the alkaline earth metal is present in the polishing composition in a concentration of about 5×10^{-3} to about 5 mmoles/kg.
13. The polishing composition of claim 12, wherein the alkaline earth metal is present in the polishing composition in a concentration of about 5×10^{-3} to about 3 mmoles/kg.
14. The polishing composition of claim 1, wherein the silica particles are present in the polishing composition in an amount of about 0.1 to about 20 wt.% based on the total weight of the polishing composition.
15. The polishing composition of claim 14, wherein the silica particles are present in the polishing composition in an amount of about 1 to about 10 wt.% based on the total weight of the polishing composition.
16. The polishing composition of claim 1, wherein the oxidizing agent is an inorganic or organic per-compound.
17. The polishing composition of claim 1, wherein the oxidizing agent is present in the polishing composition in an amount of about 0.5 to about 8 wt.% based on the total weight of the polishing composition.

18. The polishing composition of claim 17, wherein the oxidizing agent is present in the polishing composition in an amount of about 1 to about 5 wt.% based on the total weight of the polishing composition.

19. The polishing composition of claim 1, wherein the polishing composition further comprises an acid, and the acid is an inorganic acid selected from the group consisting of nitric acid, phosphoric acid, sulfuric acid, salts thereof, and combinations thereof.

20. The polishing composition of claim 1, wherein the polishing composition further comprises an acid, and the acid is an organic acid selected from the group consisting of oxalic acid, malic acid, malonic acid, tartaric acid, acetic acid, lactic acid, propionic acid, phthalic acid, benzoic acid, citric acid, succinic acid, salts thereof, and combinations thereof.

21. A chemical-mechanical polishing composition comprising:
(a) silica particles,
(b) about 5×10^{-3} to about 10 mmoles/kg of at least one alkaline earth metal selected from the group consisting of calcium, strontium, and mixtures thereof, based on the total weight of the polishing composition, and
(c) a liquid carrier comprising water,
wherein the polishing composition has a pH of about 7 to about 13.

22. The polishing composition of claim 21, wherein the polishing composition has a pH of about 8 to about 11.

23. The polishing composition of claim 22, wherein the silica particles are present in the polishing composition in an amount of about 1 to about 10 wt.% based on the total weight of the polishing composition.

24. The polishing composition of claim 23, wherein the polishing composition further comprises an oxidizing agent.

25. The polishing composition of claim 24, wherein the oxidizing agent is an inorganic or organic per-compound.

26. The polishing composition of claim 25, wherein the oxidizing agent is present in the polishing composition in an amount of about 0.5 to about 8 wt.% based on the total weight of the polishing composition.

27. The polishing composition of claim 26, wherein the oxidizing agent is present in the polishing composition in an amount of about 1 to about 5 wt.% based on the total weight of the polishing composition.

28. The polishing composition of claim 25, wherein the polishing composition further comprises an inorganic acid selected from the group consisting of nitric acid, phosphoric acid, sulfuric acid, salts thereof, and combinations thereof.

29. The polishing composition of claim 25, wherein the polishing composition further comprises an organic acid selected from the group consisting of oxalic acid, malic acid, malonic acid, tartaric acid, acetic acid, lactic acid, propionic acid, phthalic acid, benzoic acid, citric acid, succinic acid, salts thereof, and combinations thereof.

30. The polishing composition of claim 29, wherein the polishing composition further comprises a corrosion inhibitor selected from the group consisting of 1,2,3-triazole, 1,2,4-triazole, benzotriazole, benzimidazole, benzothiazole, and mixtures thereof.

31. The polishing composition of claim 30, wherein the polishing composition further comprises a complexing or chelating agent.

32. The polishing composition of claim 21, wherein the alkaline earth metal is present in the polishing composition in a concentration of about 5×10^{-3} to about 7.5 mmoles/kg.

33. The polishing composition of claim 32, wherein the alkaline earth metal is present in the polishing composition in a concentration of about 5×10^{-3} to about 5 mmoles/kg.

34. The polishing composition of claim 33, wherein the alkaline earth metal is present in the polishing composition in a concentration of about 5×10^{-3} to about 3 mmoles/kg.

35. The polishing composition of claim 21, wherein the silica particles are present in the polishing composition in an amount of about 0.1 to about 20 wt.% based on the total weight of the polishing composition.

36. The polishing composition of claim 35, wherein the silica particles are present in the polishing composition in an amount of about 1 to about 10 wt.% based on the total weight of the polishing composition.

37. The polishing composition of claim 21, wherein the polishing composition further comprises an oxidizing agent.

38. The polishing composition of claim 37, wherein the oxidizing agent is an inorganic or organic per-compound.

39. The polishing composition of claim 37, wherein the oxidizing agent is present in the polishing composition in an amount of about 0.5 to about 8 wt.% based on the total weight of the polishing composition.

40. The polishing composition of claim 39, wherein the oxidizing agent is present in the polishing composition in an amount of about 1 to about 5 wt.% based on the total weight of the polishing composition.

41. The polishing composition of claim 21, wherein the polishing composition further comprises an acid, and the acid is an inorganic acid selected from the group consisting of nitric acid, phosphoric acid, sulfuric acid, salts thereof, and combinations thereof.

42. The polishing composition of claim 21, wherein the polishing composition further comprises an acid, and the acid is an organic acid selected from the group consisting of oxalic acid, malic acid, malonic acid, tartaric acid, acetic acid, lactic acid, propionic acid, phthalic acid, benzoic acid, citric acid, succinic acid, salts thereof, and combinations thereof.

43. A method of polishing a substrate comprising the steps of:
- (a) providing a substrate,
 - (b) providing a chemical-mechanical polishing composition comprising:

- (i) silica particles,
 - (ii) about 5×10^{-3} to about 10 mmol/kg of at least one alkaline earth metal selected from the group consisting of calcium, barium, strontium, and mixtures thereof, based on the total weight of the polishing composition,
 - (iii) about 0.1 to about 15 wt.% of an oxidizing agent, and
 - (iv) a liquid carrier comprising water,
- wherein the polishing composition has a pH of about 7 to about 13,
- (c) applying the chemical-mechanical polishing composition to at least a portion of the substrate, and
 - (d) abrading at least a portion of the substrate with the polishing composition to polish the substrate.

44. The method of claim 43, wherein the substrate comprises tantalum or tantalum nitride, and at least a portion of the tantalum or tantalum nitride is abraded with the polishing composition to polish the substrate.

45. The method of claim 44, wherein the polishing composition has a pH of about 8 to about 11.

46. The method of claim 45, wherein the silica particles are present in the polishing composition in an amount of about 1 to about 10 wt.% based on the total weight of the polishing composition.

47. The method of claim 46, wherein the oxidizing agent is an inorganic or organic per-compound.

48. The method of claim 47, wherein the oxidizing agent is present in the polishing composition in an amount of about 0.5 to about 8 wt.% based on the total weight of the polishing composition.

49. The method of claim 48, wherein the oxidizing agent is present in the polishing composition in an amount of about 1 to about 5 wt.% based on the total weight of the polishing composition.

50. The method of claim 47, wherein the polishing composition further comprises an inorganic acid selected from the group consisting of nitric acid, phosphoric acid, sulfuric acid, salts thereof, and combinations thereof.

51. The method of claim 47, wherein the polishing composition further comprises an organic acid selected from the group consisting of oxalic acid, malic acid, malonic acid, tartaric acid, acetic acid, lactic acid, propionic acid, phthalic acid, benzoic acid, citric acid, succinic acid, salts thereof, and combinations thereof.

52. The method of claim 51, wherein the polishing composition further comprises a corrosion inhibitor selected from the group consisting of 1,2,3-triazole, 1,2,4-triazole, benzotriazole, benzimidazole, benzothiazole, and mixtures thereof.

53. The method of claim 52, wherein the polishing composition further comprises a complexing or chelating agent.

54. The method of claim 43, wherein the alkaline earth metal is present in the polishing composition in a concentration of about 5×10^{-3} to about 7.5 mmoles/kg.

55. The method of claim 54, wherein the alkaline earth metal is present in the polishing composition in a concentration of about 5×10^{-3} to about 5 mmoles/kg.

56. The method of claim 55, wherein the alkaline earth metal is present in the polishing composition in a concentration of about 5×10^{-3} to about 3 mmoles/kg.

57. The method of claim 43, wherein the silica particles are present in the polishing composition in an amount of about 0.1 to about 20 wt.% based on the total weight of the polishing composition.

58. The method of claim 57, wherein the silica particles are present in the polishing composition in an amount of about 1 to about 10 wt.% based on the total weight of the polishing composition.

59. The method of claim 43, wherein the oxidizing agent is an inorganic or organic per-compound.

60. The method of claim 43, wherein the oxidizing agent is present in the polishing composition in an amount of about 0.5 to about 8 wt.% based on the total weight of the polishing composition.

61. The method of claim 60, wherein the oxidizing agent is present in the polishing composition in an amount of about 1 to about 5 wt.% based on the total weight of the polishing composition.

62. The method of claim 43, wherein the polishing composition further comprises an acid, and the acid is an inorganic acid selected from the group consisting of nitric acid, phosphoric acid, sulfuric acid, salts thereof, and combinations thereof.

63. The method of claim 43, wherein the polishing composition further comprises an acid, and the acid is an organic acid selected from the group consisting of oxalic acid, malic acid, malonic acid, tartaric acid, acetic acid, lactic acid, propionic acid, phthalic acid, benzoic acid, citric acid, succinic acid, salts thereof, and combinations thereof.

64. A method of polishing a substrate comprising the steps of:
- (a) providing a substrate,
 - (b) providing a chemical-mechanical polishing composition comprising:
 - (i) silica particles,
 - (ii) about 5×10^{-3} to about 10 mmol/kg of at least one alkaline earth metal selected from the group consisting of calcium, strontium, and mixtures thereof, based on the total weight of the polishing composition, and
 - (iii) a liquid carrier comprising water,wherein the polishing composition has a pH of about 7 to about 13,
 - (c) applying the chemical-mechanical polishing composition to at least a portion of the substrate, and
 - (d) abrading at least a portion of the substrate with the polishing composition to polish the substrate.

65. The method of claim 64, wherein the substrate comprises tantalum or tantalum nitride, and at least a portion of the tantalum or tantalum nitride is abraded with the polishing composition to polish the substrate.

66. The method of claim 65, wherein the polishing composition has a pH of about 8 to about 11.

67. The method of claim 66, wherein the silica particles are present in the polishing composition in an amount of about 1 to about 10 wt.% based on the total weight of the polishing composition.

68. The method of claim 67, wherein the polishing composition further comprises an oxidizing agent.

69. The method of claim 68, wherein the oxidizing agent is an inorganic or organic per-compound.

70. The method of claim 69, wherein the oxidizing agent is present in the polishing composition in an amount of about 0.5 to about 8 wt.% based on the total weight of the polishing composition.

71. The method of claim 70, wherein the oxidizing agent is present in the polishing composition in an amount of about 1 to about 5 wt.% based on the total weight of the polishing composition.

72. The method of claim 69, wherein the polishing composition further comprises an inorganic acid selected from the group consisting of nitric acid, phosphoric acid, sulfuric acid, salts thereof, and combinations thereof.

73. The method of claim 69, wherein the polishing composition further comprises an organic acid selected from the group consisting of oxalic acid, malic acid, malonic acid, tartaric acid, acetic acid, lactic acid, propionic acid, phthalic acid, benzoic acid, citric acid, succinic acid, salts thereof, and combinations thereof.

74. The method of claim 73, wherein the polishing composition further comprises a corrosion inhibitor selected from the group consisting of 1,2,3-triazole, 1,2,4-triazole, benzotriazole, benzimidazole, benzothiazole, and mixtures thereof.

75. The method of claim 74, wherein the polishing composition further comprises a complexing or chelating agent.

76. The method of claim 64, wherein the alkaline earth metal is present in the polishing composition in a concentration of about 5×10^{-3} to about 7.5 mmoles/kg.

77. The method of claim 76, wherein the alkaline earth metal is present in the polishing composition in a concentration of about 5×10^{-3} to about 5 mmoles/kg.

78. The method of claim 77, wherein the alkaline earth metal is present in the polishing composition in a concentration of about 5×10^{-3} to about 3 mmoles/kg.

79. The method of claim 64, wherein the silica particles are present in the polishing composition in an amount of about 0.1 to about 20 wt.% based on the total weight of the polishing composition.

80. The method of claim 79, wherein the silica particles are present in the polishing composition in an amount of about 1 to about 10 wt.% based on the total weight of the polishing composition.

81. The method of claim 64, wherein the polishing composition further comprises an oxidizing agent.

82. The method of claim 81, wherein the oxidizing agent is an inorganic or organic per-compound.

83. The method of claim 81, wherein the oxidizing agent is present in the polishing composition in an amount of about 0.5 to about 8 wt.% based on the total weight of the polishing composition.

84. The method of claim 83, wherein the oxidizing agent is present in the polishing composition in an amount of about 1 to about 5 wt.% based on the total weight of the polishing composition.

85. The method of claim 64, wherein the polishing composition further comprises an acid, and the acid is an inorganic acid selected from the group consisting of nitric acid, phosphoric acid, sulfuric acid, salts thereof, and combinations thereof.

86. The method of claim 64, wherein the polishing composition further comprises an acid, and the acid is an organic acid selected from the group consisting of oxalic acid, malic acid, malonic acid, tartaric acid, acetic acid, lactic acid, propionic acid, phthalic acid, benzoic acid, citric acid, succinic acid, salts thereof, and combinations thereof.
87. The polishing composition of claim 1, wherein the silica particles is fumed silica.
88. The polishing composition of claim 1, wherein the silica particles is colloidal silica.
89. The polishing composition of claim 21, wherein the silica particles is fumed silica.
90. The polishing composition of claim 21, wherein the silica particles is colloidal silica.
91. The polishing composition of claim 43, wherein the silica particles is fumed silica.
92. The polishing composition of claim 64, wherein the silica particles is colloidal silica.